APPENDIX K-1

METHODS USED TO ANALYZE KEY ECOLOGICAL FUNCTIONS AND FUNCTIONAL REDUNDANCY OF WILDLIFE SPECIES.

This appendix describes the methods used to analyze key ecological functions (KEFs) and functional redundancy of wildlife species. At the time of this analysis, databases on habitats and KEFs of fish species were not yet developed but could be included in such analyses later.

INTRODUCTION AND DEFINITIONS

The analyses were conducted at the resolution of subwatersheds (6-HUC or hydrologic unit code level) and then summarized to the broader areas of provinces and the Columbia River Basin.

"Key ecological functions" refers to a classification of the major ecological roles played by each wildlife species (Marcot and Vander Heyden 2001), as coded in the Washington-Oregon Species Habitat Project (SHP) database (Johnson and O'Neil 2001). "Functional redundancy" refers to the number of wildlife species coded as sharing the same categories of KEFs (Brown 1995).

This analysis provides a basis for determining the potential array of KEFs present in a wildlife habitat, how those KEFs can change over time historically or under management alternatives, and how patterns of KEFs can vary geographically among wildlife habitats. The ecological basis for the analysis of functional redundancy is in the presumption that KEFs with higher levels of functional redundancy can be more resilient or resistant to changes in the environment (Jaksic et al. 1996), and that, overall, systems with greater average functional redundancy will be more diverse and functionally stable over time (Naeem 1998, Rastetter et al. 1999, Walker 1992, MacNally 1995, Peterson et al. 1998). Such assertions have not been well studied for the wildlife communities of the Columbia River Basin, so analyses of KEFs and functional redundancy should be taken as testable, working hypotheses of effects on ecosystem diversity, productivity, and resilience.

ANALYSIS METHODS

Methods are presented here using an example subwatershed to illustrate the procedure. The example subwatershed is 6-HUC 170601040901, located in the Upper Grande Ronde subbasin (4-HUC), in the Blue Mountains Province.

<u>Step 1. Map wildlife habitats and calculate area and proportion within the subwatershed</u>.

Northwest Habitat Institute produced GIS maps and data tables that display the types and areas of wildlife habitats for this subwatershed at historic and current time periods (Fig. K1, Table K1). (Wildlife habitat was also mapped at future time periods under management alternatives, but for purpose of this example we discuss only historic and current; analyses are the same.)

Data on acres of each wildlife habitat type for each time period was converted to proportions (Table K1); these will become the weighting factors for functional redundancy values.

Step 2. Determine functional redundancy by wildlife habitat.

In this step, the SHP database is queried to first list all wildlife species associated with each of the wildlife habitats that occur in the subwatershed, at each time period. The query is then linked to their KEFs so that a list of all KEF categories for all species in each wildlife habitat is produced. Next, the number of wildlife species is counted for each KEF category, in each wildlife habitat. This is a measure of functional redundancy for each KEF category, for each wildlife habitat. In practice, all this can be done simply in a single relational database query.

Two minor twists to this procedure were necessary for this specific subwatershed. (1) The wildlife habitat type "regenerating forests" is an additional habitat type created for these maps that does not appear in the original SHP list of wildlife habitats. Regenerating forests pertains to early successional stages resulting strictly from timber harvesting (mostly clearcutting) of what would otherwise be mapped as forested habitats. For this example, we cross-indexed the specific SHP wildlife habitat type represented by the "regenerating forest" category, with SHP structural condition classes representing early, post-harvest successional stages. (2) This subwatershed contains the "agriculture" wildlife habitat type. The SHP database codes for wildlife species associated with the agriculture wildlife habitat type presume the occurrence of many other native wildlife habitats adjacent to, or included within, the agricultural type. We felt this greatly overstated the wildlife species richness associated purely with agricultural conditions, so we narrowed the query of wildlife species associated with agriculture by specifying the specific structural conditions of agriculture found in this particular subwatershed, that is, "unimproved pasture" and "improved pasture." In addition, we included wildlife species only if they were "closely associated" with the agriculture type. This narrowed the field from 342 wildlife species to just over a hundred, which is far more reasonable given other experience in the interior Columbia River Basin.

With these minor tweaks, we listed the number of wildlife species associated with each KEF category, for each wildlife habitat type (Table K2).

Step 3. Account for proportion of wildlife habitats within the subwatershed.

This does not complete the process, because the amounts and proportions of each wildlife habitat type differ among types and over the time periods. To account for this, we then multiplied the (uncorrected, raw) values of functional redundancy for each KEF category for each pertinent wildlife habitat type (Table K2), by the percent of each wildlife habitat type in the subwatershed (Table K1), keeping these products separate for historic and current time periods. We called these products "weighted redundancy values." This is an interim step only and does not have any specific ecological meaning.

For example, the raw functional redundancy value for KEF category 1.1.1 (the key ecological function category "Primary consumer") in the Eastside Mixed Conifer Forest wildlife habitat type, is 121 wildlife species (Table K2). The historic proportion of this wildlife habitat type in

the example subwatershed is 0.058 (Table K1). Multiplying these values gives 121 x 0.058 = 7.1. This is the weighted redundancy value for this wildlife habitat type in this subwatershed, for this particular time period. Such calculations were done for all other wildlife habitat types in this subwatershed, and then carried into the next step.

We next summed the weighted redundancy values across all wildlife habitat types for each KEF category, again separately for historic and current conditions. This resulted in what we called the "**summed weighted redundancy values** across all habitats" within the subwatershed for historic and current time periods, for each category KEF. This is the final result of functional redundancy for each KEF category across all wildlife habitats within a subwatershed.

Following the above calculation example, the summed weighted redundancy values for KEF category 1.1.1 in the example watershed was 101 for the historic time period and 97 for the current time period. These values are the area-averaged number of wildlife species associated with this KEF category, across all wildlife habitats present in this watershed at each time period.

Using another example, KEF 3.6.3 (the key ecological function category of "creates aquatic structures potentially used by other species") had summed weighted redundancy values across all wildlife habitats of 0.2 for the historic period and 2.9 for the current period. The value increased from historic to current periods because this particular KEF is associated with open water and herbaceous wetlands, which were introduced, created, or at least newly mapped since historic times (according to the NHI database for this HUC; however, there may also be a mapping resolution or representation problem of not correctly showing open water and herbaceous wetland types under historic conditions, but this was not a problem for most terrestrial, upland wildlife habitat types).

Further, we calculated the rate of change of the summed weighted redundancy values between time periods. For historic and current periods, this is calculated as [(current - historic)/historic]. For example, for KEF 3.6.3, the change from 0.2 to 2.9 was calculated as (2.9-0.2)/0.2 = 13.5. This means that the summed weighted functional redundancy for KEF 3.6.3 increased by a factor of 13.5 (or 1,350 %) from historic to current conditions. In contrast, KEF 1.1.1 changed by (97-101)/101 = -0.04, that is, decreased by a factor of 0.04 (or 4 percent). Comparing time periods in this way aided identifying which KEFs increased or decreased the most.

We also averaged the summed weighted functional redundancy values, across all KEF categories, by adding the values across KEF categories and dividing by the number of KEF categories. This provided a value representing the **mean functional redundancy** (number of wildlife species) across all KEF categories and wildlife habitat types, for each time period. In the example watershed, mean redundancy values were 22.2 wildlife species for the historic time period and 20.6 for the current. The value decreased, but probably not significantly so. Such mean functional redundancy values do not reveal which KEFs changed, however, so one would also want to inspect the KEF category-specific values and changes. Similar mean functional redundancy values compared across time periods or subwatersheds may still result for major shifts in KEF-specific values. Still, mean functional redundancy values may be useful to track when values vary substantially.

<u>Step 4. Graph and summarize results</u>.

We then created a series of graphs showing, variously, (a) changes in the wildlife habitats for this subwatershed (Figs. K2, K3), and (b) changes in the summed weighted functional redundancy values by KEF category (Figs. K4a, K4b), as well as (c) changes in **functional richness** (the total number of KEF categories present) and mean functional redundancy (weighted functional redundancy averaged over all KEF categories), for historic and current periods (Fig. K5).

Step 5. Tally across provinces and basin

The final step entailed summarizing results across all subwatersheds with a broader area, such as province and the entire Columbia River Basin. Graphs of such tallies depict the number of subwatersheds in which the temporal changes in the summed weighted functional redundancy values increased, decreased, or remained the same.

GIS maps of such changes were particularly useful for quickly identifying geographic areas with consistent and salient changes in KEF redundancy across time periods. For instance, results for the example subwatershed suggest a decline in functional redundancy of KEF 5.1, the key ecological function category of "potentially improving soil structure and aeration by digging" (Fig. K4b). But where, geographically, have such declines occurred? Mapping subwatershed-specific changes (Fig. K6) clearly shows major areas of decline of this function, namely Willamette Valley, Columbia Basin, and Snake River Basin (the example subwatershed in the Blue Mountains also shows up as having a major decline in this function). Such maps can be produced to compare other time periods (e.g., historic to future, or current to future), to compare outcomes of management alternatives at a given time period, or to compare changes in total functional diversity or mean functional richness.

RESULTS AND DISCUSSION

For the example subwatershed explored here, there are indeed changes from historic to current time periods in the specific KEF categories. However, at the broad geographic scope of the entire Columbia River Basin, total functional richness and mean functional redundancy (Fig. K5) seem resilient to changes in wildlife habitats. This not unexpected when values are averaged across all wildlife habitats and KEF categories.

However, this example linked wildlife species (and their KEFs) only to presence of the broad wildlife habitat types, and ignored the presence and influence of specific structural conditions of each widlife habitat, as well as specific key environmental correlates (the specific substrates and habitat elements) occurring within the wildlife habitats. Many of the KEF parameters explored here may be far more sensitive when all these factors are accounted for in the calculation steps presented here.

CAVEATS AND CONFERENCES

Some caveats and cautions need to be highlighted for this kind of analysis (also see Marcot and

Vander Heyden 2001). For example:

- KEF changes are scale-sensitive and -specific, being more robust and less sensitive the larger the area is considered (HUCs, provinces)

- The changes displayed in this example do not account for vegetation structural conditions (except for regenerating forest and agricultural land) and for specific key environmental correlates. Accounting for these conditions may greatly affect KEF analysis results, that is, the KEF categories, redundancy levels, functional richness, mean functional redundancy, mapped outcomes, and changes between time periods, may all become more sensitive.

- Because such habitat factors were not considered here, the calculated levels of functional redundancy in the example presented may seem misleadingly similar between historic and current periods. It may be more ecologically meaningful to stress the *percent change* across time periods (e.g., Figs. K4a, K4b).

SUMMARY

- "(Key) ecological functions" refers to the set of ecological roles played by (fish and) wildlife in their ecosystems. Such roles can influence the capacity of the ecosystem to support other species and are important new ways of tracking effects of land planning.

- Our analysis method can aptly display the trends in ecological functions across time periods, such as historic to current, and current to future under planning alternatives.

- The trends are shown as levels of "functional redundancy" which is the average number of wildlife species playing each functional role.

- Higher redundancy may mean more resilient and robust ecosystems.

- In general, ecosystems that have "all their marbles" – that is, with all the original ecological functions still present -- can be said to be "fully functional." Our analyses can help trace the degree to which ecosystems remain fully functional under each alternative.

- The example analysis presented in this appendix can be conducted at the subbasin (or other) scale. It is more meaningful to include structural conditions of wildlife habitats, as well as key environmental correlates, with the analyses.

- For the example subwatershed analyzed in this appendix, here are some sample ecological interpretations of results of such an analysis:

o This subwatershed has gained significant amounts of agricultural (pastureland) area, Pondersoa pine forest, and herbaceous wetland habitats, and has lost most of its shrub-steppe and all of its regenerating forest habitats, from historic to current times.

o Overall, this subwatershed has remained fully functional when averaged across all its habitats, although specific locations have drastically changed in wildlife habitat, associated

wildlife species, and their associated ecological functions, within the subwatershed (such as within specific vegetation stands).

o Some of the ecological functions (examples only) of wildlife that have significantly increase since historic times are primary cavity excavation, secondary cavity use, fragmentation of standing wood, impounding of water, and creation of snags. These changes would favor species oriented around snags and tree cavities (e.g., small owls, swallows), down wood (some lizards, snakes), and water and wetlands (some waterfowl, amphibians).

o Some of the ecological functions of wildlife that have significantly declined since historic times are terrestrial burrow and runway excavation, soil turnover and aeration, and grazing alteration of vegetation structure. These changes would disfavor species oriented around terrestrial burrow use (e.g., some small mammals, lizards, others) and early successional shrub vegetation structures (some buntings, sparrows, flycatchers, and others), and may not provide as productive a soil ecosystem as occurred historically.

o It is possible, and easy, to determine which KEF categories have suffered declines, and the associated wildlife species, and thus the wildlife habitats, structural conditions, and key environmental correlates (specific habitat elements and substrates) that would be useful to highlight in a conservation or restoration program, if the objective is to provide for "fully functional" wildlife communities and ecosystems.

- And, finally, it is entirely feasible to integrate habitats and KEFs of fish into such analyses.

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